STATE OF CALIFORNIA

AIR RESOURCES BOARD

AIR MONITORING QUALITY ASSURANCE

VOLUME V

AUDIT PROCEDURES MANUAL

APPENDIX I

PERFORMANCE AUDIT PROCEDURES FOR PM10 SAMPLERS

MONITORING AND LABORATORY DIVISION

JULY 2005

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PERFORMANCE AUDIT PROCEDURES FOR PM10 SAMPLERS

MONITORING AND LABORATORY DIVISION

JULY 2005

I.1.0 GENERAL OPERATING PROCEDURE

I.1.0.1 AUDITING PROCEDURES

The primary goal of an auditing program is to identify system errors that may result in suspect or invalid data. The assessment of the accuracy of the High Volume (Hi-Vol) particulate measurement system can only be achieved by conducting an audit under the following guidelines:

A. Without special preparation or adjustment of the system to be audited.

B. By an individual with a thorough knowledge of the instrument or process being evaluated, but not by the routine operator.

C. With accurate certified National Institute of Standards Technology (NIST) traceable transfer standards that are completely independent of those used in routine calibration.

D. With complete documentation of audit data for submission to the operating agency. Audit information includes, but is not limited to: types of instruments and audit transfer standards, model and serial numbers, transfer standard traceability, calibration information, and collected audit data.

An independent observer should be present, preferably the routine operator of the sampling equipment. This practice not only contributes to the integrity of the audit, but also allows the operator to offer any explanations and information that will help the auditor to determine the cause of discrepancies between measured audit data and the sampling equipment response.

I.1.0.2 FLOW RATE PERFORMANCE AUDITS OF THE MASS FLOW CONTROLLED AND VOLUMETRIC FLOW CONTROLLED HIGH VOLUME PM10 SAMPLERS

Audit procedures provided here are specific to Hi-Vol PM10 samplers that are equipped with fractionating inlets that require an actual flow rate of 1.13 m^3/min (40.0 CFM). Audit techniques may vary among different models of samplers because of differences in required flow rates, flow controlling devices, options utilized (i.e., continuous flow recorder), and the configuration of the sampler. In this subsection, the following conditions are assumed:

A. The mass flow controlled sampler utilizes a flow sensor to adjust the flow rate by controlling the motor's output and is usually equipped with a flow recorder. The volumetric flow controlled sampler utilizes a critical flow orifice for flow control and is equipped with a flow recorder which is used to verify continuous operation of the sampler.

B. The sampler inlet is designed to operate at a volumetric flow rate of 1.13 m^3/min (40.0 CFM) at actual conditions; the acceptable (manufacturer specified) flow rate fluctuation range is ±10% of this value.

C. The certified audit transfer standard will be a BGI variable orifice equipped with a differential pressure gauge. This equipment is NIST traceable and certified once a quarter with the standard deviation within 1.5% of the last two certifications.

D. The calibration relationship for the audit variable orifice is expressed in terms of true volumetric flow rate (Qc) as indicated by the audit orifice; these units being ft^3/min [Cubic Feet per Minute (CFM)].

E. Examples of samplers used for particulate measurement are provided in Figures I.1.0.1 and I.1.0.2. The differences in equipment and theory for each sampler are shown in the diagrams. The performance audit procedures for the samplers vary due to the differences in operating procedures.

I.1.0.3 PERFORMANCE AUDIT PROCEDURES - MASS FLOW CONTROLLED (MFC) SAMPLER

The auditor should adhere to the following procedures during an audit of the MFC sampler:

A. Collect the following equipment and transport to the monitoring station:

1. A certified (NIST traceable) variable orifice device with the most recent certification report.

2. A differential pressure gauge with a range of 0-20" H_2O and a minimal scale division of at least 0.2" H_2O.

3. A temperature measuring device (i.e., thermometer, thermometer, thermistor, thermocouple) capable of accurately measuring temperature over the range of -20°C to +60°C and accurate to the nearest 1°C. It must be referenced to an NIST or ASTM thermometer and be checked annually. The thermometer should be within ±2°C on the annual check.

4. A barometer capable of accurately measuring ambient pressure to the nearest millimeter mercury (mm Hg) over the range of 500 to 800 mm Hg. The barometer must be referenced within ±5 mm Hg of an NIST traceable barometer, at least annually.

5. QA Audit Worksheet (Figure I.1.0.3).

6. Spare recorder charts, clean filters, and miscellaneous hand tools.

NOTE: The site operator is responsible for providing the sampler's calibration relationship (calibration curve or factor) for the subsequent determination of the MFC sampler's actual flow rate (Qa).

B. On the back side of a clean Dickson recorder chart, record the parameters listed below and install the chart in the recorder.

1. Sampler ID number.

2. Site name.

3. Date.

4. Auditor's names.

NOTE: Use a chart equivalent to the type of chart used by the site operator to eliminate error due to different brand variation in the chart printing. If the MFC sampler was calibrated by using square root function paper, the audit must be conducted with a similar recorder chart. Observe the recorder zero setting. Ask the operator if they normally adjust the zero as part of their weekly routine. If they do, instruct them to adjust the pen to Indicate true zero.

C. Install a clean filter in the Hi Vol PM10. **DO NOT** use a filter cassette; place the filter directly on the sampler filter screen.

D. Install the audit variable orifice on the sampler. Do not restrict the flow rate through the orifice (i.e., by using plates or closing the valve). Use an unrestricted orifice. Simultaneously tighten the faceplate nuts on alternate corners to prevent leaks and to assure even tightening. The fittings should be hand-tightened, as too much compression can damage the sealing gasket. Make sure the orifice gasket is present and the orifice is not cross-threaded on the faceplate.

E. Inspect the audit orifice device for correct zero and adjust if necessary.

F. Switch on the sampler and allow it to reach operating temperature (5 minutes).

NOTE: The sampler inlet may be partially lowered, within 2 inches, over the audit orifice to act as a draft shield.

G. Observe and record the following parameters on the QA Audit Worksheet (Figure I.1.0.3):

1. Site name, audit date, operator and auditors.

2. Check box[es] for collocated, primary, and secondary, as appropriate.

3. Sampler make, model, ID number, latest calibration date, and cal. equip. cert. date.

4. Ambient temperature (Ta) in degrees Centigrade (°C)

5. Ambient barometric pressure (Pa) in mm Hg

6. The sampler's slope and intercept, if applicable.

H. When the sampler has reached operating temperature, read the pressure drop across the differential pressure gauge on the audit device and record it as ΔP on the audit worksheet.

I. Switch off the sampler until zero is attained and repeat Step H of I.1.0.3, two more times for a total of three observations. Record the sampler's ΔP for each step on the audit worksheet.

NOTE: Make sure the operator relieves the recorder pen drag by tapping the side of the recorder before reading the chart. This ensures a true reading.

J. Confirm that the flow controller and motor are operating properly. Run the sampler with one filter in place and note the ΔP on the audit device. Without turning off the sampler, partially close the valve on the audit orifice and check that the ΔP drops and returns to the original operating point within several minutes. Then without turning off the motor, reopen the valve on the audit orifice and check again for over-shoot and verify that the ΔP again returns to the original operating point. If the flow controller and motor are not responding to this type of systems check, then a double filter test is performed. This is accomplished by the addition and removal of a second filter on top of the original filter. Check again for the correct ΔP responses and document the information on the QA Audit Worksheet.

K. Switch off the sampler and remove the audit orifice and the filter.

L. Ask the operator to calculate the station's instrument flow rate as determined by the calibration relationship and the Dickson chart reading. Find out from the operator if this value is Qstd or Qa. Enter the values into the computer program and check the appropriate box if Qstd has to be corrected to Qa. Also, choose the appropriate equation for the relationship between the Dickson chart reading and the slope and intercept, if applicable.

O. The standard flow rate Qstd, can be converted to Qa (actual flow) by using Equation 1:

$$Qa = Qstd \times \frac{760}{Pa} \times \frac{Ta}{298.15} \qquad \text{(Eq. 1)}$$

Where:

Qa = sampler's actual flow rate

Qstd = sampler's standard flow rate

Ta = ambient temperature, °K (°K = °C + 273.15)

Pa = ambient barometric pressure, mm Hg

NOTE: Subsections O through R are generated as a result of the data input into the computer. These calculations are provided to show the method used to generate percent difference.

P. Determine the true flow rate through the audit transfer standard orifice using Equation 2.

$$Qc = m \sqrt{[\Delta P(H_2O)\ (Ta/Pa)]}^{\,*} \qquad \text{(Eq. 2)}$$

Where:

Qc = true volumetric flow rate as indicated by the audit orifice, ft^3/min. (CFM)

$\Delta P(H_2O)$ = pressure change across the orifice, in Inches of water (H_2O)

Ta = ambient temperature, °K (°K = °C + 273.15)

Pa = ambient barometric pressure, mm Hg

m = slope of the orifice calibration relationship

***NOTE**: The orifice calibration relationship is equal to EPA's use of slope and intercept in the Quality Assurance Handbook, Volume II, Section 2.11.7.1.15.

Q. Determine the percent difference between the sampler actual flow rate and the corresponding audit measured true flow rate using Equation 3:

$$\% \text{ difference} = \frac{[Oa - Oc]}{Qc} \times 100 \qquad \text{(Eq.3)}$$

NOTE: Deviations exceeding ±7% will require re-calibration. Deviations exceeding ±10% require an Air Quality Data Action (AQDA) request to be issued. Upon investigation the invalidation or correction of all data from the last calibration forward or known date of change (to be determined by the reporting agency) may result.

R. Determine the percent difference between the inlet design flow rate of 40.0 CFM and the audit measured true flow rate using Equation 4:

$$\% \text{ difference} = \left[\frac{Oc - 40.0}{40.0}\right] \times 100 \qquad \text{(Eq.4)}$$

NOTE: Deviations exceeding ±7% will require an investigation. Deviations exceeding ±10% (or the acceptable design flow rate range specified by the inlet manufacturer) require an Air Quality Data Action (AQDA) request to be issued. Upon investigation the invalidation or correction of all data from the last calibration forward or known date of change (to be determined by the reporting agency) may result.

S. Generate the preliminary audit report (Figure I.1.0.4) by entering the responses recorded on the audit worksheet into the computer. The final report will be generated upon the final certification of the BGI variable orifice at the end of the quarter. These results will then be posted on the web.

I.1.0.4 PERFORMANCE AUDIT PROCEDURES - VOLUMETRIC FLOW CONTROLLED (VFC) SAMPLER

The auditor should adhere to the following procedures during an audit of the VFC sampler:

A. Collect the following equipment and transport to the monitoring station:

1. A certified (NIST traceable) variable orifice device with the most recent certification report.

2. A differential pressure gauge with a range of 0-20” H_2O and a minimal scale division of at least 0.2” H_2O.

3. A temperature measuring device (i.e., thermometer, thermistor, thermocouple) capable of accurately measuring temperature over the

range of -20°C to +60°C and accurate to the nearest 1°C. It must be referenced to an NIST or ASTM thermometer and be checked annually. The thermometer should be within ±2°C on the annual check.

4. A barometer capable of accurately measuring ambient pressure to the nearest millimeter mercury (mm Hg) over the range of 500 to 800 mm Hg. The barometer must be referenced within ±5 mm Hg of an NIST traceable barometer, at least annually.

5. QA Audit Worksheet (Figure I.1.0.3).

6. Spare recorder charts, clean filters and miscellaneous hand tools.

NOTE: The site operator is responsible for providing the sampler's calibration information and any needed equipment required (i.e., 0 to 8 in. mercury manometer) to determine the sampler's actual flow rate (Qa).

B. If the sampler has a Dickson chart, but its readings are not used to determine flow, remove it or raise the pen so the audit is not recorded.

C. Install a clean filter (within a cassette) in the VFC sampler.

D. Install the audit variable orifice on the sampler. Do not restrict the flow rate through the orifice (i.e., by using plates or closing the valve). Use an unrestricted orifice. Simultaneously tighten the faceplate nuts on alternate corners to prevent leaks and to assure even tightening. The fittings should be hand-tightened, as too much compression can damage the scaling gasket. Make sure the orifice gasket is present and the orifice is not cross-threaded on the faceplate.

E. Inspect the audit orifice device for correct zero and adjust if necessary.

F. Switch on the sampler and allow it reach operating temperature (5 minutes).

NOTE: The sampler inlet may be partially lowered, within 2 inches, over the audit orifice to act as a draft shield.

G. Observe and record the following parameters on the QA Audit Worksheet (Figure I.1.0.3):

1. Site name, audit date, operator, and auditors.

2. Check box[es] for collocated, primary, and secondary, as appropriate.

3. Sampler make, Model, ID number, latest calibration date, and cal. equip. cert. date.

4. Ambient temperature (Ta), In degrees Centigrade (°C)

5. Ambient barometric pressure (Pa), mm Hg

H. When the sampler has reached operating temperature, read the pressure deflection across the differential pressure gauge on the audit device and record as ΔP on the audit worksheet.

I. Switch off sampler until zero is attained and repeat Step H of I.1.0.4, two more times for a total of three observations. Record the ΔP for the audit device for each step on the audit worksheet.

J. Ask the operator to calculate the sampler's actual flow rate (Qa) using the same method used to determine the sampler's flow rate during normal operation.

.

K Determine the true flow rate (Qc) through the audit transfer standard orifice: (refer to Section I.1.0.3, Item O).

L. Determine the percent difference between the sampler actual flow rate and the corresponding audit measured true flow rate (refer to Section I.1.0.3, Item P).

NOTE: Deviations exceeding ±7% will require recalibration. Deviations exceeding ±10% require an Air Quality Data Action (AQDA) request to be issued. Upon investigation the invalidation or correction of all data from the last calibration forward or known date of change (to be determined by the reporting agency) may result.

M. Determine the percent difference between inlet design flow rate of 40.0 CFM and the audit measured true flow rate (refer to Section I.1.0.3, Item R).

NOTE: Deviations exceeding ±7% will require an investigation. Deviations exceeding ±10% (or the acceptable design flow rate range specified by the inlet manufacturer) require an Air Quality Data Action (AQDA) request to be issued. Upon investigation the invalidation or correction of all data from the last calibration forward or known date of change (to be determined by the reporting agency) may result.

N. Generate the preliminary audit report (Figure I.1.0.4) by entering the responses recorded on the audit worksheet into the computer. The final report will be generated upon the final calibration of the BGI variable orifice at the end of the quarter. These results will then be posted on the District's web site.

I.1.0.5 AUDIT DATA REPORTING

The operating agency should be given a copy of the preliminary audit results when the audit is completed. The preliminary data should never be used to make monitoring system adjustments. A post-audit verification of audit equipment and data is essential before inferences can be drawn regarding the sampler's performance. An auditor should be able to support audit data with quarterly pre- or post-audit equipment verification documentation.

Final verified audit data should be submitted to the operating agency as soon as possible. Delays may result in data loss. A sampler out of audit limits is also out of calibration limits, and the data collected may be invalid. If a sampler exhibits unsatisfactory agreement with the verified audit results (audit differences exceed ARB's control limits) a calibration should be performed immediately (prior to the next run day).

NOTE: Sections of the above procedure were taken from the reference "Method for Determination of Particulate Matter as PM10 in the Atmosphere", Section 2.11.7, published by the Environmental Protection Agency.

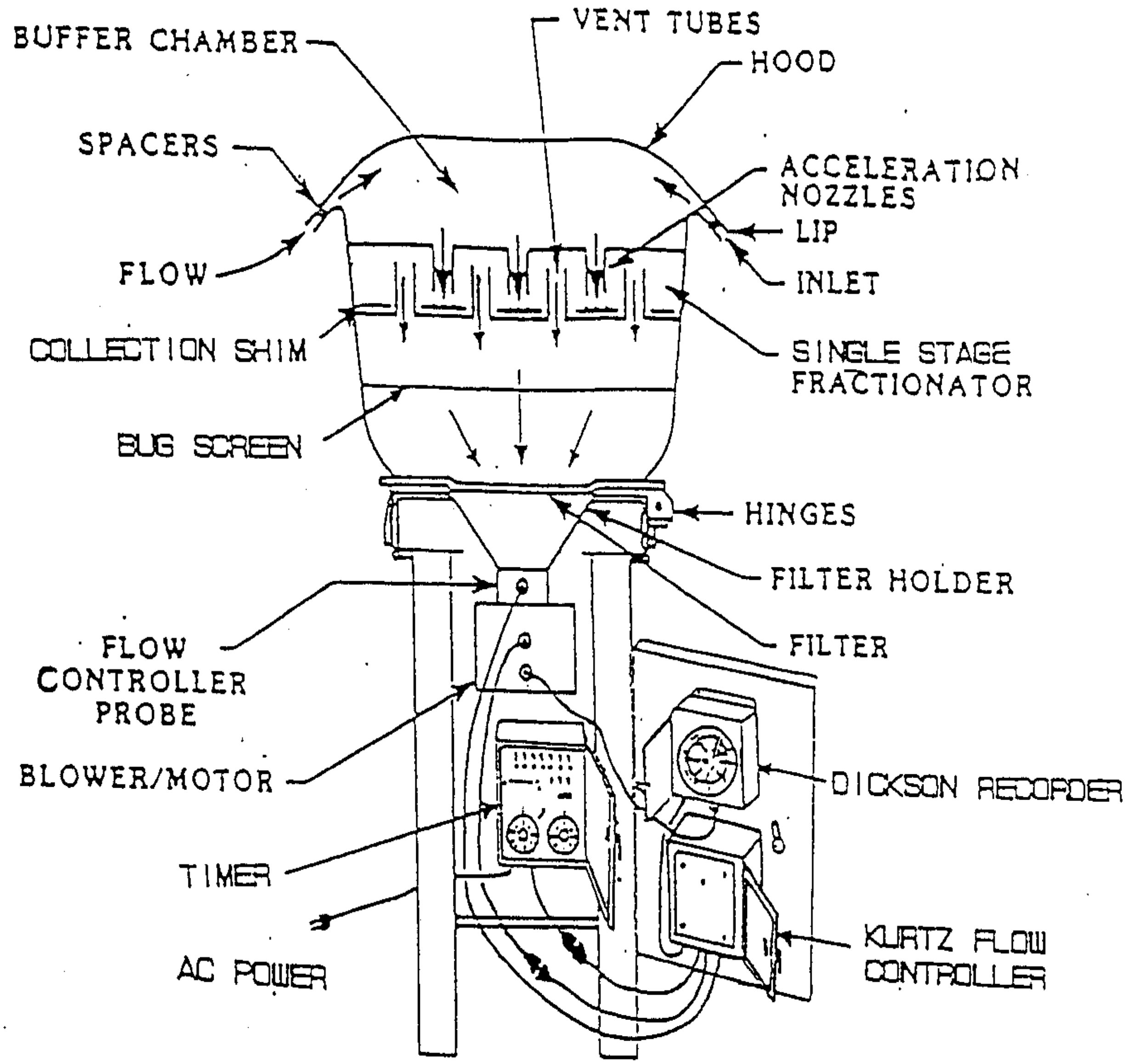

Figure I.1.0.1.

Mass Flow Controlled Sampler

Figure I.1.0.2
Volumetric Flow Controlled Sampler
Modified with a Laminar Flow Element (Magnehelic)

QA AUDIT WORKSHEET
PM10 AND TSP

Site Name: ______________________ Date: ____________

Operator: ______________________

Auditors: ______________________

Collocated Yes [ ] No [ ] Primary Yes [ ] No [ ] Secondary Yes [ ] No [ ]

Model: ______________________ ID#: ____________

Audit Orifice Delta P			
Run 1	Run 2	Run 3	Average

Station Instrument Flow Rate			
Run 1	Run 2	Run 3	Average

Cal. Date ____________ Magnehelic Reading ________ Passed FCT Yes[ ] No[ ]

Cal. Equip. Cert Date: ________ Slope: ______ Intercept: ______ Baro: ______ Temp: _____ ^oC

Collocated Yes [ ] No [ ] Primary Yes [ ] No [ ] Secondary Yes [ ] No [ ]

Model: ______________________ ID#: ____________

Audit Orifice Delta P			
Run 1	Run 2	Run 3	Average

Station Instrument Flow Rate			
Run 1	Run 2	Run 3	Average

Cal. Date ____________ Magnehelic Reading ________ Passed FCT Yes[ ] No[ ]

Cal. Equip. Cert Date: ________ Slope: ______ Intercept: ______ Baro: ______ Temp: _____ ^oC

Collocated Yes [ ] No [ ] Primary Yes [ ] No [ ] Secondary Yes [ ] No [ ]

Model: ______________________ ID#: ____________

Audit Orifice Delta P			
Run 1	Run 2	Run 3	Average

Station Instrument Flow Rate			
Run 1	Run 2	Run 3	Average

Cal. Date ____________ Magnehelic Reading ________ Passed FCT Yes[ ] No[ ]

Cal. Equip. Cert Date: ________ Slope: ______ Intercept: ______ Baro: ______ Temp: _____ ^oC

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Figure I.1.0.3
QA Audit Worksheet

Technical Appendix - Mass Flow Controlled PM10

Station/Van Audit Data & Results

Van Data Pressure Drop (inches H2O)	Station Data Indicated Flows (CFM)	Actual Flows (CFM)	Average Indicated Flow (CFM)	Average Actual Flow (CFM)	**Percent Difference**
2.90	41.7	40.5			
2.93	42.3	40.7	41.8	40.6	***3.0%***
2.91	41.5	40.5			

	Design Flows Lower Limit	Design Flows Upper Limit	**Percent Difference from Design**
Based on an actual flow of 40.6 CFM , the sampler **meets design criteria.**	36 CFM	44 CFM	***1.5%***

Audit Calculations

$$\text{Actual Flow} = \text{BGI Slope} * \text{Squareroot}\left(\frac{\text{Pressure Drop} * \text{Ambient Temp in Kelvin}}{\text{Ambient Pressure in mmhg}}\right) + \text{BGI Intercept}$$

BGI Slope = 35.8000 BGI Intercept = 0.4640

Ambient Pressure in mmhg = 701 Ambient Temp in Kelvin = 301.95

Instrument/AIRS Information

ARB Number	33164	AIRS Number	060650012
Audit Date	08/15/2002	Instrument Manf.	SIERRA ANDERSEN
Version	0	Model	SA1200
Quarter	3	Serial Number	3546
Van	B	Last Calibration	04/11/2002

General Comments

California Air Resources Board
Monitoring and Laboratory Division
Quality Assurance Section

Figure I.1.0.4
Preliminary Report Printout MFC

Technical Appendix - ARB PM10

Station/Van Audit Data & Results

Station Data: Station Magnehelic Reading	Van Data: Pressure Drop in inches H2O	Actual Flows	Indicated Flow	Average Actual Flow	Average Percent Difference
	3.13	40.7			
19.0	3.14	40.8	41.0 CFM	40.7 CFM	*0.7%*
	3.13	40.7			

	Design Flows: Lower Limit	Design Flows: Upper Limit	Percent Difference from Design
Based on an actual flow of 40.7 CFM , the sampler **meets design criteria.**	36 CFM	44 CFM	*1.8%*

Audit Calculations

Average Actual Flow = BGI Slope * Squareroot (AvgVan Orifice Pressure Drop * Ambient Temp in Kelvin) + BGI Intercept
Ambient Pressure in mmhg

Indicated Flow = (45.379*(1-(Magnehelic Reading*1.867/Ambient Pressure))-2.243)+((Ambient Temp in Celsius-25)*.059)

BGI Slope = 35.6000 BGI Intercept = 0.9790

Ambient Pressure in mmhg = 751 Ambient Temp in Kelvin = 298.65

Instrument/AIRS Information

ARB Number	52901	AIRS Number	061030002
Audit Date	06/12/2002	Instrument Manf.	SIERRA ANDERSEN
Version	0	Model	SA1200
Quarter	2	Serial Number	20005078
Van	B	Last Calibration	05/02/2002

General Comments

California Air Resources Board
Monitoring and Laboratory Division
Quality Assurance Section

Figure I.1.0.4 (cont'd)
Preliminary Report Printout VFC